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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

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First Named Inventor or Application Identifier

Eiichiro IKEDA

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APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

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1. ☒ Fee Transmittal Form
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3. ☒ Drawing(s) (35 USC 113) Total Sheets 6

4. ☒ Oath or Declaration Total Pages 2

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c. ☐ Copy from a prior application (37 CFR 1.63(d))
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[Note Box 5 below]

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Signed Statement attached deleting inventor(s)
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5. ☐ Incorporation By Reference (useable if Box 4c is checked)
The entire disclosure of the prior application, from which a copy of the
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ACCOMPANYING APPLICATION PARTS

8. ☐ Assignment Papers (cover sheet & document(s))

9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney

10. ☐ English Translation Document (if applicable)

11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☒ Return Receipt Postcard (MPEP 503)
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Status still proper and desired

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	TOTAL CLAIMS (37 CFR 1.16(c))	10-20 =	0	X \$ 18.00 =	\$ 0.00
	INDEPENDENT CLAIMS (37 cfr 1.16(b))	2-3 =	0	X \$ 78.00 =	\$ 0.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			\$ 260.00 =	\$ 0.00
				BASIC FEE (37 CFR 1.16(a))	\$ 690.00
	Total of above Calculations =				\$ 690.00
	Reduction by 50% for filing by small entity (Note 37 CFR 1.9, 1.27, 1.28).				
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19. Small entity status

- a. ☐ A Small entity statement is enclosed
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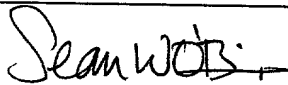
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SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

NAME	Sean W. O'Brien - Reg. No. 37,689
SIGNATURE	
DATE	July 25, 2000

SWO\ayr

SIGNAL PROCESSING APPARATUS AND METHOD THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

5 The invention relates to a signal processing apparatus and method for processing an image signal of an image pickup apparatus such as a digital camera or the like.

Related Background Art

10 Fig. 2 shows a construction of a conventional signal processing apparatus using image pickup devices of the complementary color system. Color filters of four colors of Mg (magenta), G (green), Cy (cyan), and Ye (yellow) as shown in Fig. 3 are adhered to the image
15 pickup devices every device in order. An output signal from the image pickup device is transmitted through an OB (Optical Black) circuit 201, an individual difference variation correction circuit (pixel gain circuit) 202, WB (White Balance) circuit 203, and an
20 offset circuit 204 and separately supplied to a luminance signal formation processing system and a chroma signal formation processing system.

 In the luminance signal formation processing system, a gain level difference which is caused by the
25 color filters is removed by a low pass filter (notch circuit) 215 and a clamping process is performed to a luminance signal by a Y clamp circuit 216.

Subsequently, an edge emphasis is performed by an APC (aperture) circuit 217. A level correction by color difference signals is performed by a Y compensation circuit (Ycomp circuit, luminance signal compensation circuit) 218. Thus, the luminance signal becomes a Yh luminance signal of 8 bits by a Y gamma (Y-Gamma, luminance signal gamma correction) circuit 219 having conversion characteristics as shown by a curve 502 in Fig. 5.

10 In the chroma signal formation processing system, the signal is interpolated by a color interpolation circuit 205 as if there were values in all pixels of four colors. A conversion of (the complementary colors → pure colors → color difference) is performed by a
15 color matrix circuit (color conversion circuit) 206. A subtle correction of a chroma signal is performed by a linear clip matrix circuit 207. Subsequently, a gain of chroma signal in a saturation luminance area is suppressed by a C-SUP (chroma suppression) circuit 208.
20 A band of the chroma signal is limited by a low pass filter 209. After that, a saturation is adjusted by a chroma gain circuit 210. Thereafter, the chroma signal is again converted into RGB signals by a matrix circuit 211 by a low band Yl signal and the color difference
25 signals.

The low band RGB signals become RGB (red, green, blue) signals of 8 bits by a C gamma (chroma signal

gamma correction) circuit 213 having the conversion characteristics as shown by the curve 502 in Fig. 5. Subsequently, the RGB signals are converted into color difference signals Cr and Cb by a color conversion
5 circuit 214.

An image signal is formed by the Yh signal from the luminance signal and the color difference signals Cr and Cb.

To accurately reconstruct the gradations of the luminance, therefore, a reverse gamma conversion of the monitor characteristics as shown by a curve 402 in Fig. 4 (a curve 504 in Fig. 5) is performed. Although there is a slight deviation of the hue, the accurate gradation reconstruction of the luminance is held. If there is such a gamma curve, however, the image becomes an image which lacks a contrast in a middle luminance area of a main object.

Hitherto, therefore, a gamma curve which can enhance a contrast of a draw area (middle luminance area) of the main object as shown by the curve 502 in Fig. 5 is used or a plurality of gamma curves according to the application are selectively used in accordance with a mode. In case of using the data of the curve as shown by the curve 502 in order to improve the contrast of the main object, it is necessary to further reduce the gradations in the low luminance area or high luminance area by an increased amount of the contrast in the middle luminance area. In this case, as shown in Fig. 5, particularly, in a high luminance and high saturation area of the chroma signal, an output signal difference between R and G in an output of the 8-bit C gamma circuit 213 shown in Fig. 5(a) is smaller than an output signal difference between R and G of the 8-bit C gamma circuit at the timing before the gradations of the middle luminance area in Fig. 5(c) are increased,

the saturation is deteriorated, and the output signal difference between B and G is not largely changed, so that the hue is remarkably deviated. There are, consequently, such drawbacks that the color

5 reconstruction of the high luminance area of the image after the gamma conversion deteriorates, the image is likely to be white skipped, and a discoloration occurs.

An example of the conversion of the chroma signal in case of the gamma system when the conventional 8-bit
10 C gamma curve 502 is used will be mentioned hereinbelow.

<1> 8-bit C-gamma

(a) Before gamma (11-bit RGB)

$$R = 1400$$

15 $G = 1100$

$$B = 400$$

(b) After gamma (8-bit RGB)

$$R = 236$$

$$G = 228$$

20 $B = 140$

$$Y_h = 0.3R + 0.59G + 0.11B = 221$$

(c) RGB-YCrCb conversion

$$Y_l = 0.3R + 0.59G + 0.11B = 221$$

$$Cr = R - Y = 15$$

25 $Cb = B - Y = -81$

(d) MIX with Y_h signal on the output apparatus side

$$Y_h = 220$$

$$R = Cr + Yh = 235$$

$$B = Cb + Yh = 139$$

$$G = (Yh - 0.3R - 0.11B)/0.59 \\ = 212$$

5 A ratio of the level differences among the signals of RGB remarkably differs as compared with that of the signals before the gamma conversion (refer to Fig. 5(a)). Thus, the image becomes a picture whose hue changes and which is white skipped.

10

SUMMARY OF THE INVENTION

 The invention is made in consideration of the above drawbacks and it is an object of the invention to provide a signal processing apparatus in which a color
15 crush in the high luminance area of the image after the gamma conversion can be fairly reduced and the white skip of the image and the discoloration are remarkably improved.

 To accomplish the above object, according to an
20 aspect of an embodiment of the invention, there is provided a signal processing apparatus which can output a chroma signal of m bits as a chroma signal of n bits by an output apparatus, comprising: a gamma converting unit for gamma converting the chroma signal of m bits
25 into a chroma signal of k bits; a color converting unit for converting the chroma signal of k bits obtained by the gamma converting unit into a signal of k bits

showing a brightness and a color tone; and bit
converting unit for converting the signal of k bits
showing the brightness and color tone obtained by the
color converting unit into a signal of n bits showing a
5 brightness and a color tone, wherein $m > n = k + 1$.

According to another aspect of the invention,
there is provided a signal processing method which can
output a chroma signal of m bits as a chroma signal of
n bits by an output apparatus, comprising: a gamma
10 converting step of gamma converting the chroma signal
of m bits into a chroma signal of k bits; a color
converting step of converting the chroma signal of k
bits obtained in the gamma converting step into a
signal of k bits showing a brightness and a color tone;
15 and a bit converting step of converting the signal of k
bits showing the brightness and color tone obtained in
the color converting step into a signal of n bits
showing a brightness and a color tone, wherein $m > n =$
 $k + 1$.

20 The above and other objects and features of the
present invention will become apparent from the
following detailed description and the appended claims
with reference to the accompanying drawings.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a construction
of a signal processing apparatus of an embodiment of

the invention;

Fig. 2 is a block diagram showing an example of a construction of a conventional signal processing apparatus;

5 Fig. 3 is a schematic diagram showing an example of complementary filters;

Fig. 4 is a graph showing gamma characteristics of a monitor as an output apparatus;

10 Fig. 5 is a graph showing a curve for performing each gamma converting process;

Fig. 6 is a graph showing a conversion curve of a bit adjustment circuit 120; and

15 Fig. 7 is a diagram showing an example of a conversion from chroma signals (RGB) to chromaticity signals (U, V).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 An embodiment of the invention will now be described in detail hereinbelow with reference to the drawings.

Fig. 1 shows a circuit construction of a signal processing apparatus according to an embodiment of the invention.

25 A black component is removed from a complementary signal (MgCyYe) from image pickup devices (not shown) by an OB (Optical Black) circuit 101 and a variation of the image pickup devices is corrected by a pixel gain

circuit 102. After that, a white balance is corrected by a WB (White Balance) circuit 103 and a predetermined amount of offset is added by an offset circuit 104. An output signal of the offset circuit 104 is separately
5 inputted to the luminance signal formation processing system and chroma signal formation processing system.

In the luminance signal formation processing system, a color filter level difference is removed by a notch filter (Y-LPF) circuit 115, a clamping process is
10 performed to the luminance signal by a Y clamp circuit 116, and an edge is emphasized by an APC (aperture) circuit 117. An output signal of the APC circuit 117 is corrected by a Y compensation circuit 118 by the color difference signals. A gamma correction is
15 performed by a Y gamma circuit 119 by using the C gamma curve 504 of 8 bits in Fig. 5, so that the signal becomes the Yh signal (luminance signal) of 8 bits.

In the chroma signal formation processing system, the dropped pixels of all of four colors are
20 interpolated by a color interpolation circuit 105 and the signal is converted into the complementary colors (MgCyYe) → pure colors (RGB) → luminance color difference (Yl,R - Y,B - Y) signals by a color matrix circuit 106. After a subtle color correction was
25 performed by a linear clip matrix circuit 107, a color suppression of a saturation area is performed by a C-SUP (chroma suppression) circuit 108. An output of the

C-SUP circuit 108 is band limited by a low pass filter circuit 109.

The R-Y and B-Y color difference signals (± 11 bits) which were band limited by the low pass filter circuit 109 are sent to a chroma gain circuit 110 and saturations are adjusted. The signals again become the RGB signals (11 bits) by a matrix circuit 111 by using an output signal from the chroma gain circuit 110 and the low band luminance signal Y_L . An output of the matrix circuit 111 is gamma converted by a C gamma circuit 113.

In the embodiment, an output range of the C gamma circuit 113 is set to 9 bits, thereby increasing a gradient of a gamma curve in a luminance area at a predetermined level or higher. An output range of the Y gamma circuit 119 is set to 8 bits. Output signals (RGB, 9 bits) of the C gamma circuit 113 are converted into YCrCb (CrCb = ± 8 bits (c9)) signals by a color conversion circuit 114 and adjusted to the signals of the number of bits (CrCb = ± 7 bits (c8)) of the output apparatus such as a monitor or the like by a bit adjustment circuit 120. (The luminance signal Y_L which is formed by the color conversion circuit 114 is not outputted to the output apparatus.)

The RGB signals set to 8 bits (c9) are formed by using the Y_h signal set to 8 bits from the luminance signal formation processing system and the CrCb signals

set to ± 7 bits (c8) from the chroma signal formation processing system and outputted to the output apparatus such as a monitor or the like.

5 An effect of the improvement of the color gradation reconstruction which is obtained by increasing the number of output bits of the C gamma circuit 113 as a main component element of the embodiment will be described hereinbelow.

10 In the embodiment, the number of bits of the gamma conversion of the chroma signal is set to be larger than that of the luminance gamma conversion, thereby preventing a deterioration of the color gradations. A curve 503 in Fig. 5 shows a gamma curve of 9 bits and a gradient of the curve in a range from the middle
15 luminance area to the high luminance area can be increased than that of the 8-bit gamma curve 502 because the maximum output is larger than that of the 8-bit gamma. Therefore, a level difference among the RGB signals after the gamma conversion does not change
20 to a level larger than that of 8 bits of C gamma. Thus, the saturation in the high luminance area is hardly deteriorated (refer to Fig. 5(b)).

25 The 9-bit RGB signals after the gamma conversion are subjected to an 8-bit limitation of a non-linear process by the bit adjustment circuit 120. In this case, although the CrCb signals are bit limited to the 9-bit (± 8 bits (c9)) signals, since the color

difference signals do not become extremely large even if the number of bits of the RGB signals is larger than 8, the color reconstruction is not deteriorated.

Fig. 6 is a diagram showing input (± 8 bits (c9)) -
5 output (± 7 bits (c8)) characteristics of the bit
adjustment circuit 120. When either the Cr signal or
the Cb signal enters a non-linear area at a
predetermined input level or higher and is gain
corrected, the other color difference signal is also
10 multiplied by the same gain, thereby preventing the hue
from changing. When both Cr and Cb signals enter the
non-linear area and are gain corrected, those two gains
are compared. The smaller gain is selected and
multiplied to Cr and Cb.

15 An example of the gamma conversion using the
output characteristics of RGB 9 bits according to the
embodiment will be mentioned hereinbelow.

(a) Before gamma (11-bit RGB)

R = 1400
20 G = 1100
B = 400

(b) After gamma (9-bit RGB)

R = 239
G = 242
25 B = 140

(c) RGB-YCrCb conversion

$$Y_2 = 0.3R + 0.59G + 0.11B$$

$$= 239$$

$$Cr = R - Y = 30$$

$$Cb = B - Y = -99$$

(d) Bit adjustment (± 8 bits \rightarrow ± 7 bits)

5 $Cr = 30$

$$Cb = -99$$

(There is no change in the example because the input signal levels of the bit adjustment circuit lie within the linear areas.)

10 (e) MIX (synthesis) with Y_h signal on the output apparatus side

$$Y_h = 220$$

$$R = Cr + Y_h$$

$$= 251$$

15 $B = Cb + Y_h$

$$= 121$$

$$G = (Y_h - 0.3R - 0.11B)/0.59$$

$$= 223$$

20 As mentioned above, the outputs of RGB which are obtained are based on

conversion by the 9-bit gamma curve 503

$$(R, G, B) = (251, 121, 223)$$

in response to

conversion by the 8-bit gamma curve 502

25 $(R, G, B) = (235, 139, 212)$

The saturation in case of the C gamma curve 503 of 9 bits is stronger than that of the C gamma curve 502

of 8 bits, the deviation of the hue is also smaller,
and a white skip of the color occurs less.

According to the embodiment with the above
construction, by setting the number of output bits of
5 the gamma conversion of the chroma signal to a value
larger than that of the luminance gamma conversion and
by using the gamma curve which does not reduce the
gradations of the high luminance area, a deterioration
of the color gradation reconstruction of the
10 reproduction image is prevented.

For example, when the number of input bits of the
output apparatus such as a monitor or the like is equal
to 8, in the signal processing apparatus of the
embodiment, the input of the Y gamma circuit is set to
15 11 bits, its output is set to 8 bits, the input of the
C gamma circuit is set to 11 bits, and its output is
set to 9 bits. By setting the output of the C gamma
circuit to 9 bits as mentioned above, when the 8-bit
gamma is used, the gradient in the luminance area at
20 the saturated predetermined level or higher can be set
to be larger, and the color crush can be fairly
reduced.

To form the final RGB image signals by mixing with
the output luminance signal Yh of the Y gamma circuit,
25 the output signals (RGB, 9 bits) of the C gamma circuit
are color converted into the YCrCb signals. The CrCb
signals obtained by the color conversion are non-

linearly operated to the bit width (± 7 bits) of the
output apparatus in accordance with the bit width of
the output apparatus. In the non-linear arithmetic
operation, even if the RGB signals have the range of 9
5 bits, the color difference signals do not increase
extremely so long as the saturation and the illuminance
are not abnormally large. Even if the signals after
the color difference conversion are non-linearly
converted and the number of bits is reduced, a
10 resultant picture is not adversely influenced.
Therefore, if the C gamma curve as shown by the curve
503 in Fig. 5 is used, for example, the color
reconstruction, white crush, and change in hue
(discoloration) in the high luminance area are
15 remarkably improved.

[Another embodiment]

Although the CrCb conversion has been performed in
the color conversion circuit 114 in the embodiment,
YUV conversion can be also performed in accordance with
20 a format of the output apparatus at the post stage. In
this case, a chroma signal conversion is executed in
the color conversion circuit 114 by using the following
arithmetic operations.

$$Y = 0.2990 \times R + 0.5870 \times G + 0.1140 \times B$$

25 (The converted Y signal is not actually outputted
to the output apparatus.)

$$V = 0.5000 \times R - 0.4187 \times G - 0.0813 \times B$$

$$U = -0.1684 \times R - 0.3316 \times G + 0.5000 \times B$$

The chromaticity signals U and V obtained by the color conversion circuit 114 as shown in a conversion example of Fig. 7.

- 5 Even in case of performing the CrCb conversion in the color conversion circuit 114, if the maximum output of the C gamma circuit 113 is set lest the output exceeds ± 7 bits (in the embodiment, it is sufficient to set the maximum output to 365 or less), such a
- 10 construction that one upper bit is omitted and only eight lower bits are outputted can be obtained in the bit adjustment circuit 120. With respect to UV conversion, same process can be applied. According to such construction, a burden of processes in the bit
- 15 adjustment circuit 120 at the post stage is reduced.

WHAT IS CLAIMED IS:

1. A signal processing apparatus which can output a chroma signal of m bits as a chroma signal of n bits by an output apparatus, comprising:

5 gamma converting means for gamma converting the chroma signal of m bits into a chroma signal of k bits;

color converting means for converting the chroma signal of k bits obtained by said gamma converting means into a signal of k bits showing a brightness and a color tone; and
10

bit converting means for converting the signal of k bits showing the brightness and color tone obtained by said color converting means into a signal of n bits showing a brightness and a color tone,

15 wherein $m > n = k + 1$.

2. An apparatus according to claim 1, wherein said color converting means converts the chroma signal into color difference signals (Cr, Cb).

20

3. An apparatus according to claim 2, wherein said bit converting means linearly converts a signal at a predetermined input level or lower in the color difference signals (Cr, Cb) of k bits obtained by said
25 color converting means into color difference signals (Cr, Cb) of n bits and non-linearly converts a signal at the predetermined input level or higher into the

color difference signals (Cr, Cb) of n bits.

4. An apparatus according to claim 1, wherein
said color converting means converts the chroma signal
5 into chromaticity signals (U, V).

5. An apparatus according to claim 4, wherein
said bit converting means omits one upper bit in the
chromaticity signals (U, V) of k bits and outputs n
10 lower bits.

6. A signal processing method which can output a
chroma signal of m bits as a chroma signal of n bits by
an output apparatus, comprising:

15 a gamma converting step of gamma converting the
chroma signal of m bits into a chroma signal of k bits;

a color converting step of converting the chroma
signal of k bits obtained in said gamma converting step
into a signal of k bits showing a brightness and a
20 color tone; and

a bit converting step of converting the signal of
k bits showing the brightness and color tone obtained
in said color converting step into a signal of n bits
showing a brightness and a color tone,

25 wherein $m > n = k + 1$.

7. A method according to claim 6, wherein the

chroma signal is converted into color difference signals (Cr, Cb) in said color converting step.

8. A method according to claim 7, wherein in said
5 bit converting step, a signal at a predetermined input level or lower in the color difference signals (Cr, Cb) of k bits obtained in said color converting step is linearly converted into color difference signals (Cr, Cb) of n bits and a signal at the predetermined input
10 level or higher is non-linearly converted into the color difference signals (Cr, Cb) of n bits.

9. A method according to claim 6, wherein the
15 chroma signal is converted into chromaticity signals (U, V) in said color converting step.

10. A method according to claim 9, wherein in
said bit converting step, one upper bit in the
chromaticity signals (U, V) of k bits is omitted and n
20 lower bits are outputted.

ABSTRACT OF THE DISCLOSURE

In a signal processing apparatus which can output a chroma signal of m bits into a chroma signal of n bits by an output apparatus, the chroma signal of m bits is gamma converted into a chroma signal of k bits, the gamma converted chroma signal of k bits is converted into a signal of k bits showing a brightness and a color tone, and the signal converted into the signal of k bits showing the brightness and color tone is converted into a signal of n bits showing a brightness and a color tone. Thus, a signal processing apparatus in which a color crush in a high luminance area of an image can be remarkably reduced and a white skip of the image and a discoloration are remarkably improved is provided.

FIG. 1

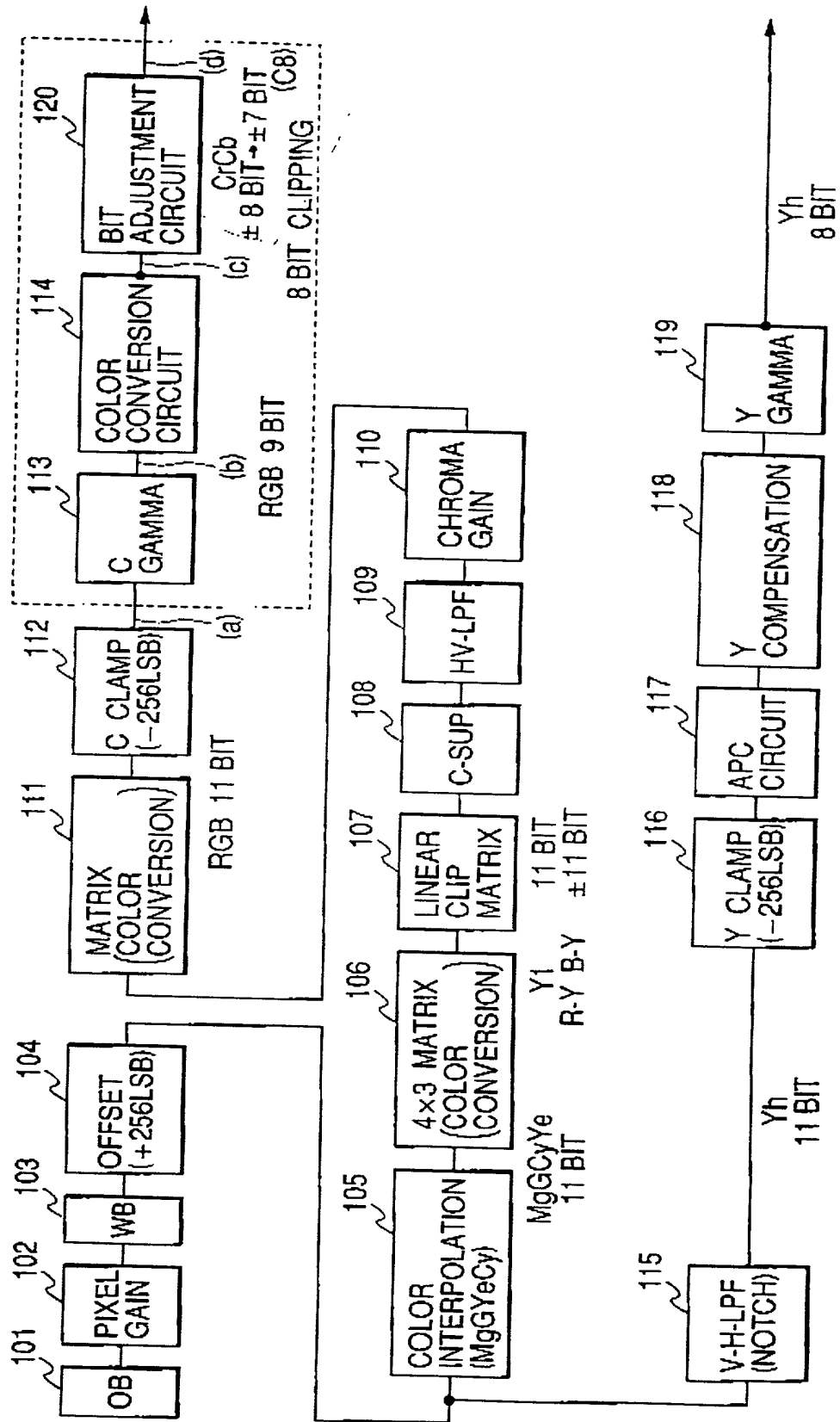


FIG. 2

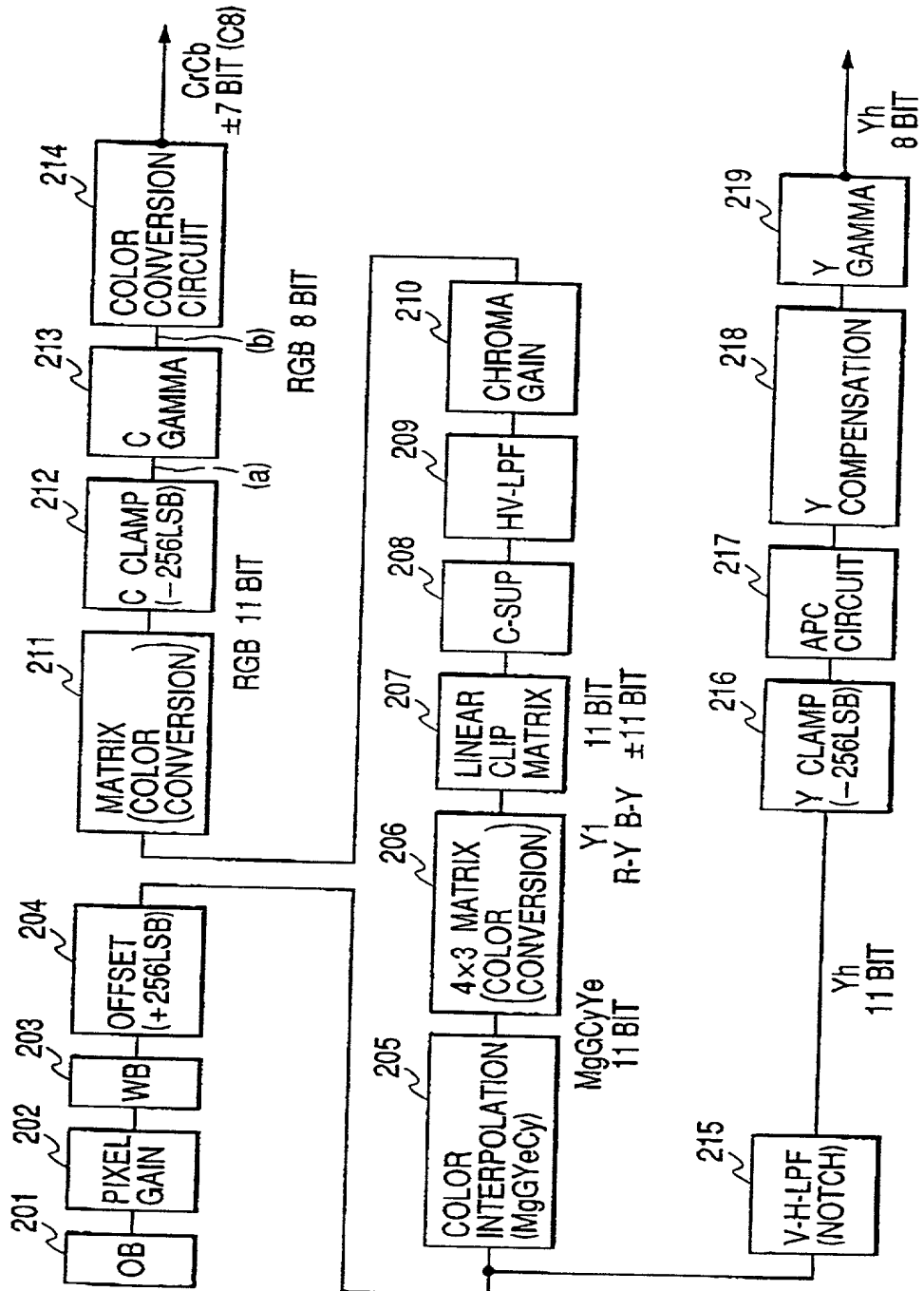


FIG. 3

Mg	G	Mg	G
Cy	Ye	Cy	Ye
Mg	G	Mg	G
Cy	Ye	Cy	Ye

FIG. 4

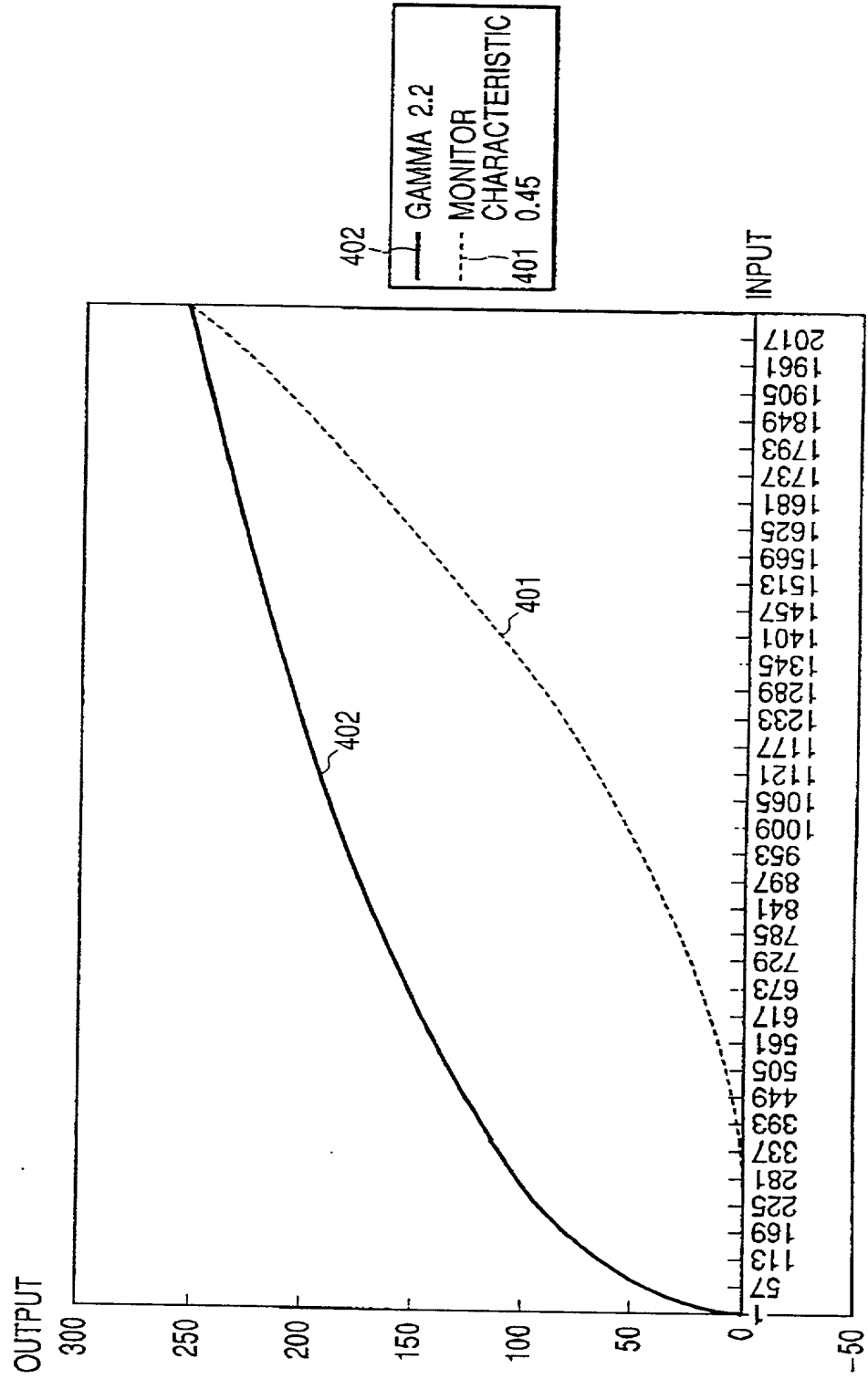


FIG. 5

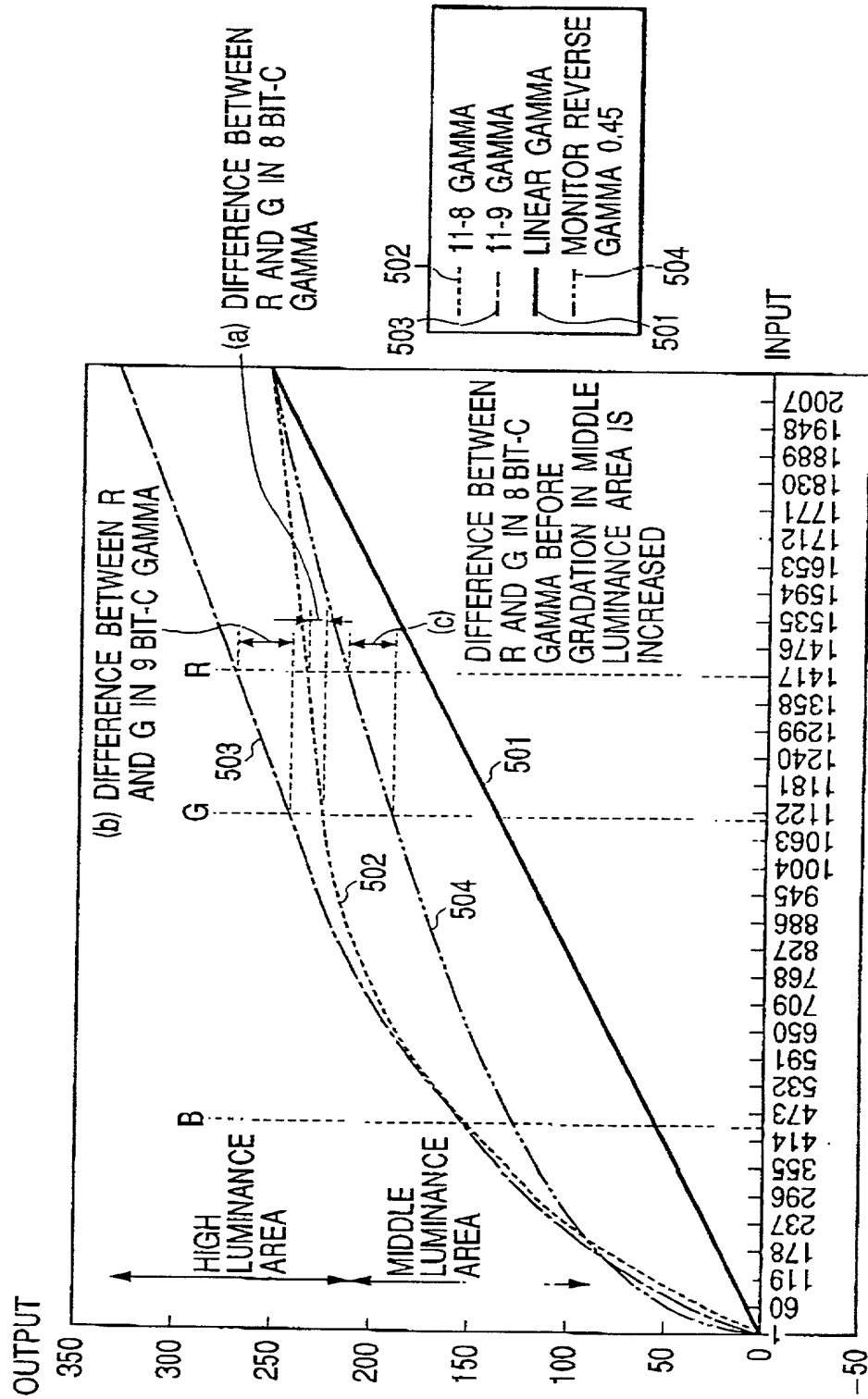
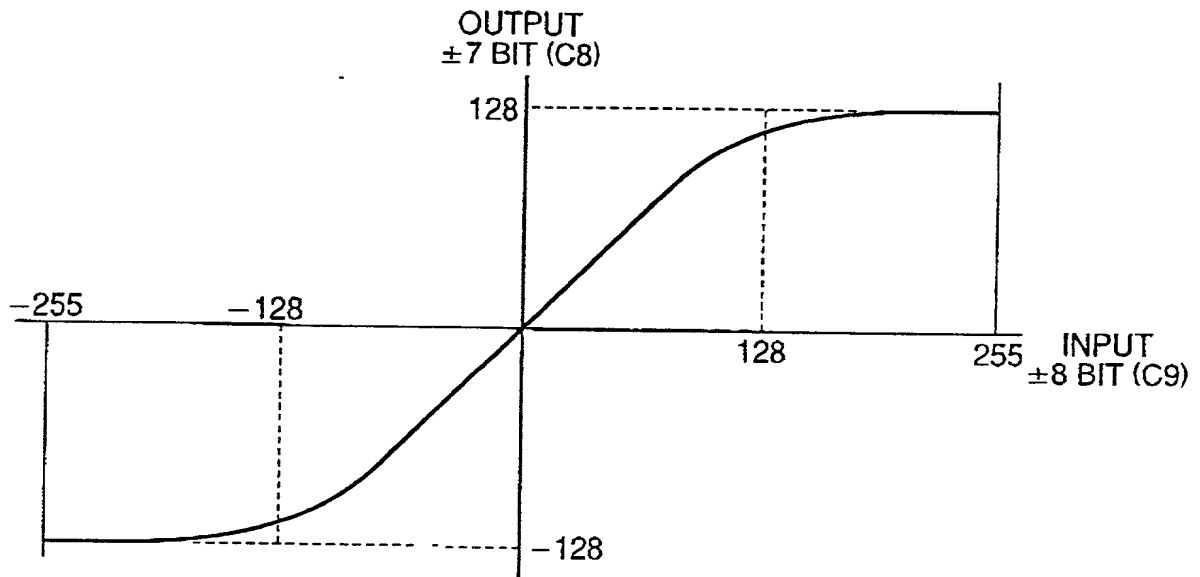


FIG. 6*FIG. 7*

R	0	0	0	510	510	510
G	0	510	510	0	510	510
B	0	0	510	0	0	510
U	0	-213.537	-255	255	41.463	0
V	0	-169.116	85.884	-85.884	-255	0

**COMBINED DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION**

As a below named inventor, I hereby declare that

My residence, post office address and citizenship are as stated below next to my name

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled _____
SIGNAL PROCESSING APPARATUS AND METHOD THEREOF

the specification of which ☒ is attached hereto ☐ was filed on _____ as United States
Application No. or PCT International Application No. _____
and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b), of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application which designates at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

Country	Application No.	Filed (Day/Mo./Yr)	(Yes/No) Priority Claimed
JAPAN	11-212645	27/JULY/1999	Yes

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application

Application No	Filed (Day/Mo./Yr.)	Status (Patented, Pending, Abandoned)
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

COMBINED DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION

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